RIO ALGOM CORPORATION
Lisbon Mine

LaSal Route
MOAB, UTAH 84532

Phone: (801) 259-5904

May 9, 1980

Mr. Ron Daniels
Coordinator of Mined Land Development
Division of Oil, Gas and Mining
1588 West North Temple
Salt Lake City, Utah 84116

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DIVISION OF
OIL, GAS & MINING

Dear Ron:

You may recall that I suggested that a 100 foot concrete plug was a lot thicker than necessary. As the cost of these plugs has arisen due to your requiring an escrow for the mine reclamation, I would like to draw your attention to some proven facts.

The proven formula, as shown in the attached information is:

$$\text{Plug length} = \frac{\text{Area of plug x pressure head}}{\text{perimeter of plug x shear stress}}$$

In our case, the highest aquifer is 1,000 feet up from the station so the pressure head would be 1000 x .43 lbs./sq. inch.

Both our ventilation and production shafts are 18 feet in diameter and concrete lined.

Pressure = 430 lbs./sq. inch
Area = 36,658 sq. inches
Perimeter = 679 inches
Shear stress = 85 lbs./sq. inch [1]

$$\text{Plug length} = \frac{36,658 \times 430}{679 \times 85} = 273 \text{ inches}$$

$$= 22.76 \text{ ft.}$$

This assumes that all pressure is from below the plug. In actual fact, there is seepage from the aquifers where the shaft passes through them, so this water would be on top of the concrete plug and the pressure above and below the plug would be equalized and theoretically you would only require a plug of infinite thinness merely to prevent mixing of the water below the plug with that above the plug.

Yours very sincerely,

M. D. Lawton
Manager

MDL:jem
Enclosures

Cc: Dave Bird,
Parsons, Behle & Latimer
File

P.O. BOX 61820
MARSHALLTOWN TVL.

A further factor which may be taken into account in the siting of plugs is that of the working conditions under which the plug is to be installed. One of the main aspects in this regard is that of ventilation, particularly in "hot" mines. Obviously under emergency conditions no wide choice exists in selecting sites which are, or which can be, adequately ventilated.

DESIGN CONSIDERATIONS

Examination of the literature has revealed that very little has been published on the design of underground plugs. What literature has appeared is largely of academic interest only and of little application to the problems encountered in South Africa.

FORMULAE FOR CALCULATING LENGTH OF PLUG

A number of formulae have been derived for the calculation of the length of the plug, many of which are based on the simple theory that the total thrust on a plug is resisted by punching shear around its perimeter.

Haniel and Lueg (7) have derived an expression for the calculation of plug length which is based on the assumption that the maximum shearing stress, which occurs at about the middle of the length of the plug, should not exceed the permissible shear stress of either the surrounding rock nor of the material of which the plug is constructed.

The maximum shear stress is calculated as being 1.5 times the average shear stress, i.e.

$$T_{max} = 1.5 \times \frac{p}{f} \text{ lb/sq. in.}$$

where p = total load on plug
f = surface area of contact between plug and surrounding rock.

/The ...

The length of the plug is then calculated from

$$l = \frac{1.5\ p}{2\ (b + h)\ T_{max}}$$

where b = breadth of plug
h = height of plug.

Kegel (8) calculates the minimum length of a plug on the assumption that the average shear stress is not greater than the permissible shear stress, so that

$$l = \frac{p}{2\ (b + h)\ T}$$

Fritzsche (9) gives the following formula for calculating the length of the plug in a circular shaft:

$$l = \sqrt{\frac{0.55\ pr^2}{\sigma}} \text{ metres}$$

$\sqrt{\frac{.55 \times 30.48 \times 7.53}{5.9755}}$
$= 4.6$ metres
$\simeq 15$ ft

in which r = radius of shaft in metres
p = water pressure kg/sq. cm.
σ = allowable tensile strength of walling or concrete kg/sq. cm.

For calculating the length of a plug, σ is taken to be 1/10 compression strength.

Schluter and Abeles (10) have derived formulae (Appendix II) for calculating the dimensions of plugs.

Elsewhere Kegel (4) has presented formulae and acceptable stresses for use in calculations for a timber dam (Appendix IV) and for the minimum thickness of rock "plugs" between underground workings and areas or strata filled with water under pressure (Appendix V).

Garrett and Campbell Pitt (11) who made observations on the experimental plug at West Driefontein, have presented graphs (Figures 9 and 10) based on data on pressure gradients through the plug which may be used to calculate the length of a plug. As the results of the work of these authors indicate, a purely theoretical approach to the problem is not entirely satisfactory, because of the other factors, such as the nature of the ground, the presence of geological fissures, etc. which have to be taken into account in deciding upon the length of a plug.

/These ...

These authors have also suggested (11) a formula for calculating the length of a plug from the height and width of the plug, the pressure on the plug and the compression on the rock or concrete. The derivation of this formula is given in Appendix VII, as is also a simplified formula for calculation of plug length suggested by Gibbs and Buley (13).

The accuracy of these expressions has been questioned by Ockleston (14) who has suggested a formula based on shear stress. The derivation of Ockleston's formula is given in Appendix VII, and also discussed under the heading "Considerations arising from recent experimental work in South Africa".

The Government Mining Engineer (15) (see also Appendix X) has laid down the following formula for the calculation of the length of plugs:

$$\text{Plug length} = \frac{\text{area of plug x pressure}}{\text{perimeter of plug x shear stress}}$$

in which the value for shear stress is 85 lb/sq. in. for concrete placed in the normal manner and 120 lb/sq. in. for colgrouted concrete plugs where positive contact between rock and concrete is assured by subsequent pressure grouting.

The Ontario Department of Mines has published specifications (16) (see also Appendix IX) and tables for use in the design and construction of underground concrete bulkheads and dams. For the sake of simplicity of calculation, the bulkhead is designed as a two-way slab simply supported on four sides. The thickness is calculated for bending moment or shear, whichever is critical, with a minimum value of three feet to allow for proper placement of the concrete.

VERTICAL PLUG AT FREDDIES NORTH LEASE AREA, LIMITED

Some details of the design and construction of a vertical plug in No. 2 Shaft, Freddies North Lease Area, Limited, have been given by Cooke (49).

Calculations

The 36 ft. concrete plug was installed in a concrete-lined flooded shaft immediately below the pump station, which is 1,850 ft. below the collar, as part of the operations concerned with recovering the shaft which had been flooded. The position of the plug in the shaft is shown in Figure 18.

The dimensions of the shaft were 47 ft. x 11 ft. inside the concrete lining, with steel buntons 7 in. x 9 in. spaced at 10 ft. vertical intervals and 6 ft. 9 in. centres horizontally, thus forming a seven-compartment shaft. Two of the compartments were reserved for upcast ventilation behind a 9 in. concrete brattice wall. Permanent shaft columns had not at that time been installed and the temporary columns comprised a 6 in. air main, four $1\frac{1}{2}$ in. ranges for water service and cementation and a 4 in. rising main.

By providing suitable pumping facilities, the calculated pressure on the underside of the plug was not greater than 424 lb/sq. in. which was about 53% of the pressure which the plug would eventually have to withstand.

The underside of the plug was at a depth of 1,910 ft. below surface, and, assuming that the head of water was, say, 70 ft. below surface, the pressure on the plug would be :

1,840 x 0.43 = 797 lb/sq. in.
= 58 tons/sq. ft.
With a shaft area of 517 sq. ft.
Total upthrust = 30,000 tons.

The formula used for calculation of the thickness of plug was :

/Thickness ...

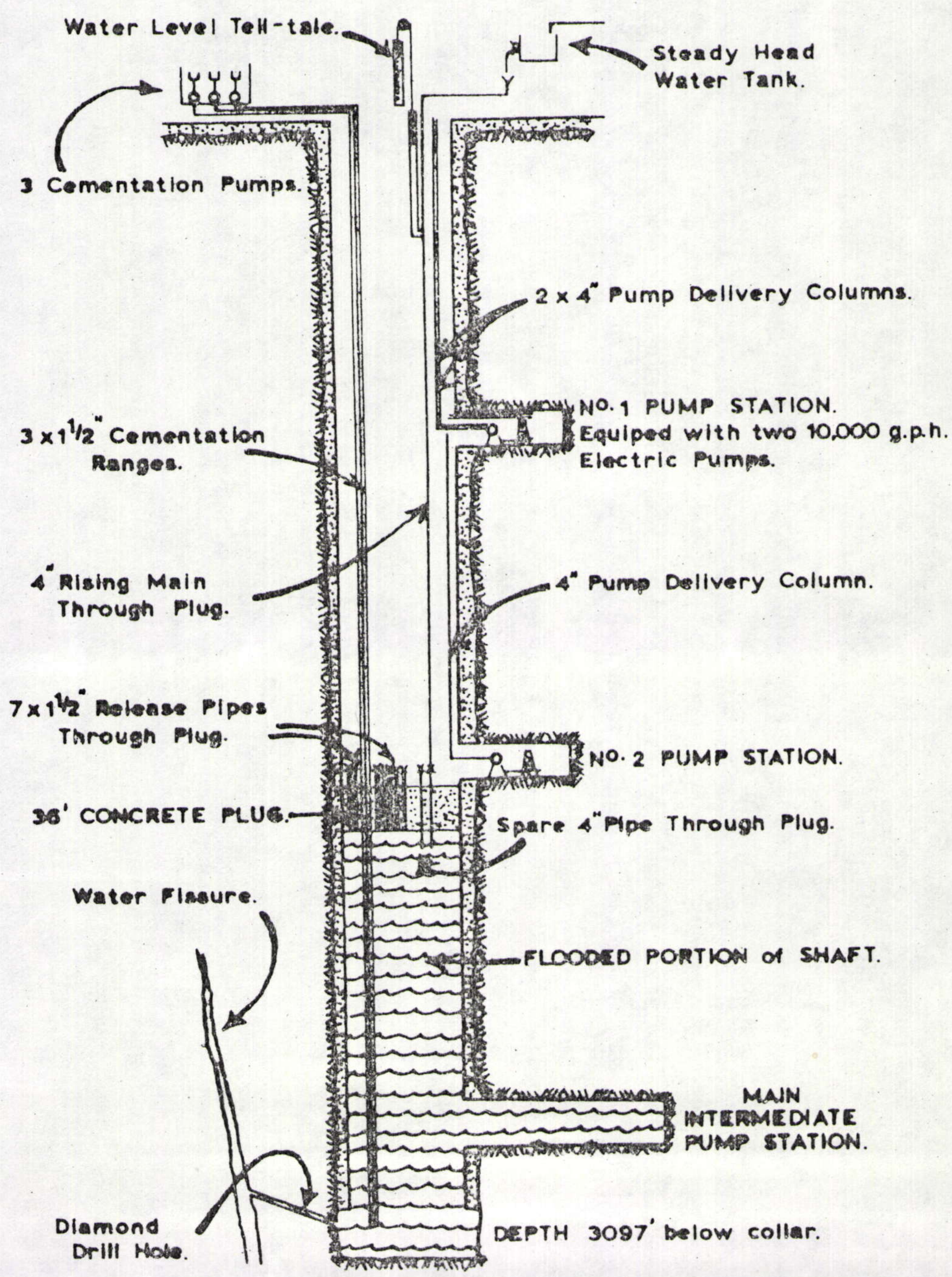
Water Level Tell-tale.
Steady Head Water Tank.
3 Cementation Pumps.
2 x 4" Pump Delivery Columns.
No. 1 PUMP STATION. Equiped with two 10,000 g.p.h. Electric Pumps.
3 x 1 1/2" Cementation Ranges.
4" Rising Main Through Plug.
4" Pump Delivery Column.
7 x 1 1/2" Release Pipes Through Plug.
No. 2 PUMP STATION.
36' CONCRETE PLUG.
Spare 4" Pipe Through Plug.
Water Fissure.
FLOODED PORTION of SHAFT.
MAIN INTERMEDIATE PUMP STATION.
Diamond Drill Hole.
DEPTH 3097' below collar.

Figure 18

$$\text{Thickness (in.)} = \frac{\text{Area of plug in sq. in. x lb. press/sq.in.}}{\text{Perimeter of plug in in. x K}}$$

(where K = shear stress of concrete $\pm$ 100 lb./sq. in.)

$$= \frac{517 \times 144 \times 797}{116 \times 12 \times 100}$$

$$= 425 \text{ in.}$$

$$= 35 \text{ ft.}$$

Construction

Because of the limited time available in which to construct the plug, the idea of stripping the concrete shaft lining and cutting hitches into the shaft walls was abandoned. The concrete for the plug was poured within the concrete shaft walls. Adhesion of the plug to the concrete shaft lining was obtained from the shear strength of the 18 enclosed buntons and of about 600 steel pins (old drill steel) which were inserted into the concrete lining before construction of the plug was started. Unevenness of the surface of the concrete lining also contributed to the adhesion of the plug to the concrete shaft lining.

In order to avoid leakage of water either at the plug/lining interface or at the shaft lining/shaft wall interface, provision was made for cementating these contacts by means of 33 pipes in the plug.

The position of these pipes is shown in Figure 19. In addition, three cementation ranges and three 4-in. pipes were provided. A platform was provided to support the concrete plug, as shown in Figure 19.

Erection of the platform installation of the 39 pipes, removal of all guides, cables and other pipes, and the insertion in the sidewalls of the drill steel pins occupied 26 hours, and the pouring of the concrete plug (765 cu. yd.) took 32½ hours.

The concrete mixture used for the first half of the plug consisted of nine parts stone, six parts sand and one part cement (rapid hardening). No reinforcement other than the buntons referred to was used.

/Because ...

DIVISION OF OIL, GAS, AND MINING

BOND ESTIMATE

OPERATOR: Rio Algom Corporation FILE NO. ACT/037/001
MINE NAME: Lisbon Mine (Two (2) Shafts)
LOCATION: Sec. 21, 22, 27, 28, T. 29 S., R. 24 E.
COUNTY: San Juan County, Utah
DATE: September 13, 1976

Operation	Amount	Rate	Cost
A. CLEAN-UP 1. Removal of structures & equipment. 2. Removal of trash & debris. 3. Leveling of ancillary facilities pads and access roads.	*This estimate is based on interior production shaft dimensions of 14'x14' and ventilation shaft of 8'x8'*		
B. REGRADING & RECONTOURING 1. Earthwork including haulage and grading of spoils, waste and overburden. 2. Recontouring of highwalls and excavations. 3. Spreading of soil or surficial materials.	*Subsurface plugs would be a compacted spoil fill to an elevation above the uraniferous Moss Back Member and a 100' high cement plug poured on the spoil.* ie 100' of fill and 100' cement is way too much		
C. STABILIZATION 1. Soil preparation, scarification, fertilization, etc. 2. Seeding or planting. 3. Construction of terraces, waterbars, etc.			
D. LABOR 1. Supervision. 2. Labor exclusive of bulldozer time.	*10 men-120 hrs*	*$ 10/hr*	*$ 12,000*
E. SAFETY 1. Erection of fences, portal coverings, etc. 2. Removal or neutralization of explosive or hazardous materials.	*26,000'^{3} of cement* *(2) surface cement caps*	*3/ft^3* *@ 1,500.*	*78,000* *3,000*
F. MONITORING 1. Continuing or periodic monitoring, sampling & testing deemed necessary.			
		Subtotal	*$ 93,000*
G. OTHER 1. *Inflation*	*10 years*	*5%*	*58,487*
		***TOTAL*	*$ 151,487*

Incorrect